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appear highly probable, if we reflect how fascinating to a large portion of the intellectual world must be the idea of helping the economists out of their perplexities by an infusion of new ideas, and by the application of the same methods which have yielded such brilliant results in the physical sciences. To show that no other method than that already described can be successfully applied to purely economic questions has been one of the principal objects of the present article.

It is with no disposition to undervalue general sociology that we express the hope that it will not supersede any part of the old-fashioned political economy in the curricula of our colleges. Even combining the two will be subject to the danger of leading the student into forgetfulness of the different methods which must be applied to them, and losing sight of any clearly marked line between what is to be regarded as scientific certainty and what is not. In consequence, he will fail to form a clear and definite idea of the manner in which public questions pertaining to revenue, to foreign trade, to domestic industry, and to the currency are to be approached. These are questions on which every influential citizen should be able to form an intelligent opinion; and he can no more do so without a clear conception of the peculiar mode of action of causes in the industrial world, than he can understand the workings of an engine without a knowledge of mechanical principles.

SIMON NEWCOMB.

ART. II. — GEOGRAPHICAL AND GEOLOGICAL SURVEYS.

II. GEOLOGICAL.

IN a previous article we have discussed the subject of Geographical Surveys, and now turn to those which are known by the term "Geological." Our object, at present, is, to explain why geological surveys have been instituted in different parts of the world, and by all, or nearly all, civilized states; then to show, in a general way, what has been accomplished by them in other countries, and also, and more particularly, in our own.

We shall then be prepared to consider what is needed, in a State like Massachusetts, in the way of geographical and geological work, in order that the public interests may be best cared for, and the claim which our people generally make, that they have a right to take a high rank among civilized communities, be justified, in that which concerns a thorough knowledge of their territory and the development of its resources.

And, to arrive at a satisfactory result, it will be desirable, in the first place, not so much to explain what geology is, as to show what the economical bearings of the science are, and how it connects itself with the material welfare and progress of the State; and, with this object in view, the relations of different governments to the mining interest will be set forth, although necessarily in a very concise way, since a full development of the subject, demanding not less than a whole volume, would be quite out of place here. That geological surveys are in some way expected to be of great value to the community is evident from the fact that they have been extended over so large a portion of the most enlightened countries; and that important results have been attained may also be taken for granted, because these surveys are constantly gaining in extent and in the scope and magnitude of the work undertaken. And yet, in this country at least, it is very doubtful whether more than a small number of the people really have any just appreciation of the nature of the operations of a thorough geological survey, while it is certain that there are but few persons who have sufficient knowledge of the subject and confidence in the value of the work done to be able to use it as it ought to be used, in order that a full return for the outlay incurred may be obtained.

All know, more or less definitely, something of what the science of geology is; and that while the geographer has to do with the surface of the earth, the geologist has not only to look at the surface, but also to endeavor to ascertain what is beneath it. Geography is one of the plainest and most straightforward of sciences. The mapping of the earth's surface, or the exhibiting on paper of its physical features, and the delineation of its artificial subdivisions, are tasks of great ease and simplicity. Work it is, to be sure, which demands

time and patience, and which requires the expenditure of a great deal of money, where accuracy is desired: but there is nothing of theory or hypothesis about it. When, however, we enter the domain of physical geography, or that more general form of the subject which has for its object the investigation of the laws governing the system of physical movements which take place upon the surface of the earth, we find ourselves in presence of a much more difficult task. The majestic sweep of the oceanic currents, the disturbances of the atmospheric equilibrium, the theory of the tides,—these and kindred subjects demand, not only prolonged and accurate observations, but the aid of the highest mathematical analysis; and we may feel assured that many years will elapse before all the problems presented to the investigator in this department will be solved. It is where physical geography ends that geology begins; and, as we go backward in time and endeavor to ascertain how the great dynamic agencies now moulding the earth's surface worked in the earlier epochs of its existence, we follow a road which is continually becoming blinder and more difficult.

Indeed, it has been, and often is, made a matter of reproach to geologists that their science is one in which hypotheses and theories predominate over facts; and it is especially urged against it, that it does not furnish numerical results—that its fancies are many and its figures few. This is, indeed, true, and yet geology has done more than any other science to correct the former erroneous ideas of men in regard to the length of time during which the earth itself, and man upon its surface, have been in existence. The results of geological investigation, although not capable of being put into figures, are as grand as any with which astronomy has furnished us; and that which the latter science has done to enlarge our conceptions of the extent of space cannot be considered as having had any more powerful influence on the intellectual development of mankind than have the revelations of geology in regard to the immensity of time required to allow for the occurrence of that complicated series of changes which the study of the earth's surface, and such of its interior as is accessible to us, has shown to have taken place. It is true

that the temptation to theorize and speculate, on a basis of small knowledge, may justly be charged against many who would consider that their claims to be called workers in geological science are beyond dispute. It is true also that for centuries geology consisted of little or nothing except speculations, many of which were wild and fanciful; but the last half-century has seen an immense change in this respect. Following the lead of the Geological Society of London, the really earnest workers in this line of research have accumulated a body of facts which it is already extremely difficult for any one man to handle. The Transactions and Proceedings of the various important societies exclusively devoted to geology form a library of no insignificant size; and the reports of the various official and government surveys fill a goodly length of shelving in one's library. Indeed, if geology has its imaginative and poetic side, it has another one of quite the opposite character. Let one examine, for instance, the bulky royal-octavo volume of the English Geological Survey, devoted chiefly to the details of sections of wells about London, and he will find that figures do there most abound. What can be more matter-of-fact than a sheet of coal-mine sections, in which, in a series of hundreds of alternations of beds of shales, grits, and coal, the thickness of each particular stratum is given with accuracy, as well as the minutest details of the peculiarities of its lithological structure! And these data, which are not obtained without much labor, but which look so unattractive to those not specially interested, may be of the greatest importance to persons mining or owning property in the region where the sections in question have been prepared, and they may be studied with the closest attention, and with results bearing directly on the welfare of the people, when placed in the proper hands.

The difference between geology and astronomy may be illustrated by comparison between the study of the phenomena of an eclipse and an earthquake, both of them events which in ancient times struck terror into the hearts of the multitude, although in the case of the eclipse the feeling could have been one of unreasoning apprehension only, while the earthquake was known to have been often highly destructive in its effects,

and therefore with reason to be dreaded. Now, the exact time of the occurrence of the next eclipse can be given with precision, because it depends on one simple law, always the same in its action, so that the motions and positions of the heavenly bodies can be ascertained by the aid of mathematical analysis for any future, as well as for any past epoch. The phenomena of the earthquake, on the other hand, depend on several causes which are not regularly recurrent in their action, and which in their mutual play acquire a degree of complexity which puts it quite out of our power to say at what particular epoch the tension of the crust will have reached such an amount, at any particular spot, that a seismic disturbance or earthquake will take place. After the shock has occurred, a great deal of important information can sometimes, if the conditions are favorable, be obtained as to the depth at which the shock originated, the way in which the vibration was propagated, and the manner in which its effects were made evident upon the surface. Looking at the matter from a general point of view, it can be shown what regions are most liable to severe disturbances, and the architect and engineer can be cautioned as to the necessity of planning their constructions so as to offer the greatest amount of resistance to the devastating agency. Thus interesting and important scientific as well as practical results are obtained, a portion of which are given approximately in figures; while by means of the combination of a great number of observations — which may perhaps have to be continued for centuries — we may at length arrive, not to that point where we shall be able to predict the time of the occurrence of earthquakes (which would, from some points of view, be a misfortune), but rather to a complete understanding of the causes of these terrible catastrophes, and of the best methods of providing against their effects.

It is chiefly through its intimate connection with the art of mining and the development of the mineral resources of the country, that geology has acquired the importance which it now has, and especially in its relation to the state. But little has ever been done by any government to encourage scientific research where there was not some pretty direct practical result to be attained. It is only within the most recent times

that the fostering of investigations made for the purpose of extending the boundaries of science, and not with an eye to any immediate practical application, has begun to be recognized as a duty. It is true, however, that in some branches of science — notably in astronomy — governments have been led to do a great deal for abstract science and to pay liberally for work which could, at present at least, only be seen to be very remotely connected with the material progress of the people. But this has only been by fits and starts, just as the right string in the popular mind happened to have been struck, or when the sentiment of international rivalry had been called into play. Thus England, after many years of the most profound indifference to Arctic discovery, suddenly awoke to the idea that this line of inquiry was of the greatest importance: the brilliancy of the achievements of the Germans and the Americans could not but be admitted, and must be surpassed. Thus, too, in the observations of the recent transit of Venus, where it would be difficult to demonstrate that the results would have any other than an exceedingly remote practical value, all the European nations vied with each other as to which should send forth the most thoroughly equipped band of observers. It was generally admitted everywhere that this was the proper thing to do. But when Gilliss went to South America and established an observatory for the purpose of determining the distance of the sun by observations on Mars, hardly an observatory could be found in the world willing to go a little out of its regular routine for the purpose of making the necessary corresponding observations; and not a government lifted its finger in help, even when the expense incurred would have been absolutely insignificant, as compared with that of the late Venus expeditions. Again, that the patronage bestowed by governments on scientific research is fitful in the extreme may be illustrated by the indifference of the Ministry and the people in England to the deep boring now going on for the purpose of settling some points in geology bearing, not so very remotely, on questions of the highest commercial importance to the country. There is, in this case, not that immediate brilliant result to be attained which happens to fall in with the dominant fancies of the people; in short, that kind of thing is not exactly in fashion at the present moment.

In the matter of the encouragement of science through the means of geological surveys the governments of Europe have, almost without exception, shown themselves far-sighted and liberal in their expenditures; but it is the practical which has been aimed at, and the scientific results have been had, into the bargain, without having been at all looked forward to as a part of the *quid pro quo*. Indeed, the way in which geological surveys have come into being in Europe is something not at all a simple matter as it is with us; but they have resulted, in most cases more or less indirectly, from the connection of the governments with the mining interests,—a connection which dates back to before the time when geological science had any existence.

If the phenomena of coal deposits, as well as of iron to some extent, are comparatively very simple and only require care and accuracy for their setting forth, so that capital may have a solid basis of fact on which to rest, this is far from being the case with most of the occurrences of the metalliferous ores. Metal mining is proverbially uncertain, and in proportion as it is uncertain, so it is attractive. Nature has stored away in the bowels of the earth many great prizes and a prodigious number of blanks; and human nature is such that there are few things about which it is accustomed to get more excited than in regard to occurrences of metalliferous indications, especially those of the metals styled precious. No one who has not had practical experience of these matters can realize how much energy and time have been used up in foolish mining enterprises, especially on the western side of our continent, and how much fraud and rascality have been mixed up with the development of our metallic wealth. It is safe to say that, for years, half the resources of the State of California were wasted in profitless and foolish “prospecting,” or preliminary attempts at mining; and it is a well-known fact that several times in its earlier history that State was completely demoralized by the “rush” *—thus wild and senseless migrations of bodies of miners from one mining region to another are termed—of

* See “Mining in the Pacific States of North America,” by J. S. Hittell, San Francisco, 1861, p. 29, *et seq.*, for a description of the Frazer River “rush” in 1858, as a specimen.

a large portion of its male population to some new El Dorado, where many of them left their starved bodies, while the rest came back in poverty and rags.

It is partly owing to this peculiar tendency of men to wasteful and heedless squandering of time and money where mining matters are concerned that the civilized European governments have, from time immemorial, taken this department of industry under their special charge. But there is another important element to be taken into consideration in this connection: this is, the sovereign right of the state to the metallic treasures buried beneath the surface.

At the present time, the object of governments in interfering with mining matters is chiefly to prevent foolish and extravagant expenditures and a wasting of the resources of the country; the idea of the divine right of the sovereign to the metals — precious or base — found beneath the surface has, to all intents and purposes, been abandoned by the enlightened states of Europe. But this has not been brought about without hundreds of years of struggles and contest, in which popes, emperors, princes, and the people have all played their parts. In this country no such complications have ever arisen. The individual States have never attempted to exercise any sovereign right over the treasures buried beneath the surface as distinct from the soil itself. The general government, as the actual owner of the soil over a large part of the country, as already shown, has had full control of all that exists upon or beneath it; and whenever Congress has done anything in reference to the sale of the mineral lands of the country, it has been because the United States was the exclusive owner of the ground, and not because there was any question of exercising the rights formerly claimed by sovereigns over the minerals and ores discovered within their territories. To undertake to show how and by what complicated series of steps the different states of Europe have been brought to their present stand-point in regard to mining matters would occupy far too much space in this connection. It need only be stated, in a few words, that it has been brought about because governments have become more enlightened, and because sounder ideas of political economy are now prevailing. It is seen to be for the best interest

of the state that mining should be as little hampered as possible ; that people who are willing to risk their capital in this way should be encouraged under wise restrictions to go on ; that the owners of the soil should not have it in their power to obstruct others who are willing to incur the risks which they themselves decline. And yet it is fully recognized that men must be guided by the light of science in their expenditures, and be restrained, as far as possible, from wasting their own money, and more especially from wantonly destroying the wealth existing beneath the surface. For every mineral deposit is of limited extent, and it is the state's interest that no more than is necessary should be lost in the working. A mine may be so unskillfully handled as to make it necessary that it should be abandoned long before it is exhausted, thus, to all intents and purposes, annihilating, so far as the public use is concerned, a portion of its contents ; or the ores taken from it may be wastefully treated in the processes of dressing and smelting which they have to undergo in order to obtain the metal from them. Here is a source of immense waste, against which it is the duty of the state to guard. For the metallic wealth included within the bosom of old mother Earth is not like the riches which her surface so bountifully provides. Forests will in time spring up again to replace those which have been recklessly removed. Exhausted soils may be made to recover their fertility ; but the contents of a mineral vein or deposit are there once for all, and if wasted in their removal the loss can never be repaired.

To understand something of the present position of the principal European states with reference to mining and geological work, it will be well to examine into what France, Germany, and England are doing in the way of encouraging and protecting the development of their mineral resources, by wise laws regulating the working of mines, facilities afforded for the highest instruction in this department, and minutely accurate surveys of their territories. And we may begin with France, a country where there are few important mineral deposits, except those of coal and iron ; while these are usually of such a character as to make their working difficult and expensive, so that the help of scientific control has been of great value, partly in checking foolish expenditures and partly by directing work

in progress, so that the best results might be attained, and the element of uncertainty eliminated, so far as this was possible.

In France, the Corps des Mines was established in 1781 ; and, about the same time, the Ecole des Mines. This mining school was first an elementary one ; it afterwards underwent several modifications, and finally became an institution into which a small number of the graduates of the École Polytechnique and those standing highest could be admitted as “*élèves ingénieurs*,” and a few more as “*élèves externes*,” on passing the necessary examinations. The “*élèves ingénieurs*” are, to all intents and purposes, government officers ; but they can only be promoted to the rank of “*ingénieur des mines*,” and be charged with the duties of that position, after passing through the course of the Ecole des Mines.

The Polytechnic School is a government institution, the object of which is to give students an opportunity of receiving a thorough mathematical training, as preparatory to admission to various branches of the public service, and especially such as call for this kind of preparation for their successful pursuit. These branches are the artillery, the engineer corps, the hydrographical corps, the mining corps, the corps of roads and bridges, the general staff, the telegraphic service, the manufacture of powder, and the management of the government monopoly of tobacco. The course of the Polytechnic School lasts two years ; and the pupils, on finishing it, designate the branch of the public service to which they wish to be admitted, and are appointed, as vacancies occur, in the order of the rank with which they are graduated after the final examinations have been passed. From an inspection of the records for some years back, it would appear that the students who stand highest are inclined, in a considerable majority of cases, to select the mining corps in preference to any other department of the service. The instruction in the Polytechnic School is not exclusively mathematical, although this class of studies largely predominates. Physics, chemistry, German, and drawing are among the other subjects taught. The “*élèves ingénieurs*,” after two or three years at the Ecole des Mines, on passing the required examinations, become “*ingénieurs des mines*,” and are immediately employed in the government service, the nature

of their work being exceedingly varied and important, since they have to represent and advise the government in all matters connected with the concession and working of mines and quarries, as well as the building and management of railroads and steam motive-power in general. The scientific investigations of the "ingénieurs des mines" are given to the world in a periodical forming two thick octavo volumes a year, and published continuously since 1794, first as the "Journal des Mines," and, since 1816, as the "Annales des Mines," the whole forming a series of volumes replete with valuable information relating to mines and railroads, not only in France but throughout the world. The mining statistics are published in a separate work of quarto size, issued once every six or seven years. In these volumes the most minute details of the yield of all the mines in France are given, with a great deal of additional information in regard to the commercial aspects of the mining and mineral interests. For instance, a diagram map is issued, on which, at a glance, can be seen exactly whence each district derives its supply of coal; or, if obtained from more than one source, then the proportionate amount from each region of supply is indicated, so that the facts can be clearly and easily made out by simple inspection.

Under the French law, all excavations for metallic ores, mineral substances, or building materials are divided into three classes, — *mines*, *minières*, and *carrières*, or mines proper, mineral deposits worked by surface excavations, or such as are open to the daylight, and quarries. No mine can be opened or worked without a government concession, and then only under the strictest supervision on the part of the proper authorities. The proprietor of the surface can open and work a quarry on his own land, without any special interference on the part of the state, except so far as may be necessary to secure the safety and health of his workmen and his neighbors. A surface deposit, worked in a *minière*, may be opened and utilized by the proprietor of the soil, if he sees fit to do so; and, if not, he cannot prevent other properly qualified persons from occupying the premises for that purpose, security being given for the payment of such damages as may accrue. A *mine*, that is, a deposit of ore which has to be worked by under-

ground excavations, cannot be utilized, even by the owner of the soil, without a concession from the government; so that, for all practical intents and purposes, the ownership of ores lying deep beneath the surface is entirely separated from the ownership of the surface itself.

Thus we see that the French government has entire control of the mining interests; that it supports a School of Mining, and takes great pains to have the men who go to it educated in the most thorough manner, giving them a five-years' course, selecting them by competitive examination at the beginning, and only allowing them to pass from the general to the special school of science on proof of extraordinary diligence in their studies. We see, also, that careful record is kept of everything that is done towards the development of the mining interests, both from a scientific and a commercial point of view; that the statistics of mining are published in full, as well as a great deal of scientific material connected with the exploration and working of the metalliferous ores and of all other economically valuable substances obtained by quarrying or mining.

One of the duties of the French Mining Engineers has been, from the time of the institution of the corps, the examination of the geological structure of the country, with a view to the development of its mineral resources. The first attempt at what would now be designated as a geological survey was in 1811. At that time, Brochant de Villiers, professor of geology in the Ecole des Mines, presented to the government a plan for making a geological map of the French Empire; but, in the troublous times which followed, the work came to naught. In 1822, the subject was taken up again, the immediate incitement thereto being the publication of Greenough's Geological Map of England; and, in 1825, the work was commenced, the gentlemen intrusted with it, all professors in the mining school, having been allowed a year for travelling in England and preparing themselves by the study of the geology of that country. The result of this survey was a map, with accompanying text, published in 1840, after more than ten years of labor. It was on a scale of 1:500,000, in six sheets, which, when put together, made a square of a little over six feet; it was by far the finest

work of the kind which had, up to that time, been executed. In 1868, the importance of maps on a large scale, on which details could be given, having become fully recognized, the work was taken up again, and this time on a scale of 1 : 80,000. One of the peculiar features of the new map is this: that the explanatory text is so prepared that it can be attached to the different sheets as they are issued, either laterally or else by pasting on the back when the sheet is mounted on cloth. Thus map and illustrative text will always be together and ready for use. No less than 1,113 different symbols are used on this map for the purpose of designating every variety of mineral occurrence which can possibly be of economical importance; these symbols are used in addition to the usual geological colors, by which the range and extent of the different groups of strata, under their scientific names, are given. There are also sheets of vertical and horizontal sections, on various scales, to suit the nature of the locality, as well as photographic views.

The course of the Prussian government in reference to mining matters, although differing in some details, is, on the whole, very similar to that of France. The new Prussian mining law dates back to 1866 only; previous to that, the government had for centuries been working itself from darkness towards light, as knowledge became more generally diffused and correcter ideas of political economy began to prevail. Mining is of very ancient origin in Germany, and a large number of our own mining terms have come to us from that country through Cornwall. And there was, for hundreds of years, a triangular contest going on there between the sovereigns, the princes, and the people in regard to the rights and privileges of the miner. Many things were done in those early days which would seem strange to us if we had not our own Congress to look to for a parallel. For instance, we find at one time that it was forbidden to increase the number of coal-mines, lest the expense of so many deep workings should raise the price of the combustible! However, it will not be possible to go back to the past and trace the progress of more liberal ideas finally culminating in the present law, which places things on an entirely satisfactory basis. As in France, property in the minerals is distinct from property in the soil. The state makes no claim except

to regulate, and receives only a very small proportion of the produce of the mine as a return for the necessary expenses of oversight. Any one can "prospect," or obtain a concession to work a mine, on any one's land, by taking proper steps and paying for the damages. The government, as in France, has a Mining Corps, a school where men are trained to the profession, and takes care that nothing shall be done which shall tend to cripple or waste the resources of the country. A quarterly journal is published, with a folio atlas of plates, in which the statistics of all the mines in the empire are given with accuracy and in the greatest detail, and all important improvements in mining and smelting discussed. This publication, as a whole, stands at the head of what is now doing in this line, the French "*Annales des Mines*" having decidedly fallen off in value within the past few years. A great part of the Prussian territory has, from time to time, been geologically mapped, under authority of the government, and a bureau of geological surveys, the "*Landesanstalt*," is now fully organized, and the publication of a series of maps on a scale of 1 : 25,000 has been commenced. An immense impetus has been given to the mineral industry of Prussia by borings and other explorations made under the directions of the state, and which have resulted in important discoveries leading to the establishment of entirely new branches of manufacture, based on the occurrence of economically valuable mineral substances existing in immense quantities, but which lie far beneath the surface, and would never have been discovered had it not been for the costly underground researches made in accordance with the indications furnished by a study of the geological structure of the country. In no country has the economical value of this kind of scientific work been more clearly demonstrated than in Prussia; and it may be mentioned in this connection, that it is there that the earth has been penetrated by boring to the greatest depths yet reached by man, namely, a little over 4,300 feet.

In Great Britain the relations of the government to the mining interest are much less direct than on the Continent, and are, in the main, limited to police regulations, having for their object the safety of the men employed and the limitation of the hours of labor for women and children. England and Scotland are

countries, however, where mining is a business of immense importance, as will be easily understood when it is mentioned that the make of iron amounts to 7,000,000 tons, and the product of coal to 125,000,000 tons per annum. And in the mining and smelting of the ores of lead, copper, zinc, and tin, England has a vast amount of capital employed. And as Great Britain stands first and foremost of all countries in the magnitude of her metallic and mineral developments, so the government has, especially within the past quarter of a century, been very active in promoting a scientific investigation of these interests, and in putting them on a substantial basis of accurate knowledge.

The geological survey of the United Kingdom began, in connection with the ordnance survey, by the employment of De la Beche to make an investigation of the important mining district of Cornwall and Devon. This was in 1835, and his report was published four years later. Soon the value of the work became apparent, and a separate organization was determined on for the geological survey, which has ever since been carried on with activity. The collections of the survey increased rapidly in importance and interest, and in 1851 the magnificent building in Jermyn Street, in which these collections were deposited, was opened to the public. Here, too, a mining school was established on a liberal scale, so that the Survey, the Museum of Practical Geology, and the Mining School are all parts of one harmonious whole. The work of the survey is carried on at the same time in England, Scotland, and Ireland by corps in a measure independent of each other, but all under one director-general in London. The publications are already very numerous, comprising geological maps, sections, and printed volumes, all made with the most scrupulous accuracy, and on a very large scale. The ordinary sheets are on the one-inch scale; the coal-fields are laid down on the scale of six inches to a mile. While the cost of an entire set of the publications of the survey is necessarily very large, any one may have a geological map of a region in which he may be specially interested, and the necessary descriptive and illustrative text, for a few shillings. The statistics of the produce of all the mines, as well as detailed plans of the same, are kept at the Mining Record Office, and a full abstract of them published every year.

When we turn to inquire what has been done and is now doing in our own country in the way of developing our mining interests, by geological surveys, mining schools, and the like, we have, in the first place, to distinguish between State and United States authority; and we will first notice the relations of our general government to mines, mineral lands, and mining education and development.

The United States being now, or having been, as has already been set forth in the first part of this article, the owner of most of the territory outside of the older States, that is, of nine tenths of the whole country, has had, of course, the right to control the mining interests, and either to sell or lease any portion of its territory; although that the government has had the power, was perhaps not quite so clear. The first action of Congress seems to have been in 1807, when the government lead-bearing lands in the Mississippi Valley were ordered to be reserved from sale, and the granting of leases was authorized. None, however, were actually issued until 1822; and but a small quantity of lead was raised previous to 1826, from which time the production of this metal began to increase rapidly. For a few years the rents demanded by the government were collected with tolerable regularity; but soon large amounts of mineral land began to be fraudulently taken up as agricultural; and, the miners refusing to make any further payments of rent, the government was quite unable to force them to do so. It was therefore, in 1847, found necessary to do away with the leasing, and to allow the lead-bearing lands to be sold, since they had been a source of constant embarrassment and of no profit while the leasing system was in force. Exactly the same thing was done in the Lake Superior country, after the lands lying to the south of that lake had been ceded by the Chippeways. The copper-bearing ranges, and a great deal of barren country besides, were covered with leases obtained from the War Department, each of which included at first tracts of nine square miles, and afterwards of one. This issue of leases, however, was suspended in 1846, as being illegal; and in 1847 Congress passed an Act authorizing the sale of the lands, regardless of whether mineral or not; and a geological survey was authorized at the same time, for the purpose of designating

what tracts should be sold as mineral land, the price of this being fixed at double that of the agricultural.

A problem of much greater magnitude came up for solution when it was discovered that a large portion of the remote and, as it was supposed, desolate region west of the Rocky Mountains contained more or less of the precious, as well as of other, metals; while over an area of considerable extent the amount of gold to be had by means of entirely unskilled labor was quite unprecedentedly large. A commissioner was sent to California to report on the matter, — a politician, of course, — and he enlightened the world with curious theories as to the origin of the gold in the detritus, but could afford little help to the government in reference to the way in which a small percentage of the gold which was being carried off from the public lands at the rate of sixty or seventy millions a year should find its way into the treasury of the country. It was quite plain, however, to most persons, that nothing could be done, except to wait until conditions changed, or the gold was all carried off. The miners were a too powerful body to be interfered with; and if an army had been sent to California to coerce them into paying, the soldiers would themselves have turned miners, thus only increasing the difficulty. The let-alone policy was therefore strictly adhered to, and for nearly twenty years after the first discovery of the gold by the Americans nothing whatever was done either toward selling or leasing the auriferous tracts, or regulating the ways and doings of the miners thereon. The diggers, of all nations, occupied the land as if it were their own. They made such rules and regulations as suited themselves, — a new set for each new district; and when they disagreed they fought it out, with a good deal of help from the lawyers, and occasional appeal to the revolver or the Henry rifle as the least expensive and most satisfactory way of getting judgment. When, however, the placer diggings began to be pretty much exhausted, portions of the river-beds having been worked over as much, in some instances, as a dozen times, and at each time with diminishing profit; when quartz and hydraulic mining, requiring perseverance and a good deal of skilfully invested capital, came to be the chief methods of mining; and, especially, when it began to

be found desirable to dispose of mines of doubtful value to foreign capitalists ; — then it gradually became apparent to mining men that it would be convenient to have a title, and that a position from which one could not be ousted by force, nor by the changing whims of a new body of occupants of the adjacent soil, might be a desirable thing, even if a small sum had to be paid to the United States in return for these advantages. Thus, at last, after years of discussion, pro and con, and when the discovery of the silver-bearing veins of Nevada had quite thrown the gold of California into the shade, making permanency of occupation of the highest importance, Congress took up the matter of the sale of the public mineral lands in the Pacific States ; and, in 1866, almost twenty years after the first discovery of gold in California and the consequent rush of emigration thither, an Act was passed entitled “An Act granting the right of way to ditch and canal owners over the public lands, and for other purposes,” the “other purposes” being much the most important ones, and including, among other things, provisions for the sale of the mineral lands. This Act was somewhat amended in 1870 ; and, in 1872, another one was passed, entitled “An Act to promote the development of the mining resources of the United States,” modifying and repealing a part of former laws on this subject, and leaving the matter nearly in this form : “All valuable mineral deposits in lands belonging to the United States, both surveyed and unsurveyed,” are declared to be free and open to exploration and purchase by citizens of the United States and those who have declared their intention to become such, “under regulations prescribed by law, and according to the local customs or rules of miners, in the several mining districts, so far as the same are applicable and not inconsistent with the laws of the United States.” Mining claims, “upon veins or lodes of quartz or other rock in place bearing gold, silver, cinnabar, lead, tin, copper, or other valuable deposits heretofore located,” shall be governed as to length along the vein or lode “by the customs, regulations, and laws in force at the date of their location.” But any claim made after the passage of this Act must not exceed 1,500 feet in length on the lode, or 300 feet in width, neither shall it be less than 25 feet in width on each side of

the middle of the vein. All persons already holding claims are confirmed in possession of them ; but their sides are limited by vertical planes ; that is, the idea of "square claims" is maintained, and not the old Spanish custom of regulating the inclinations of the sides of the location to correspond with the dip of the lode. This is a most beneficial provision, and its enforcement by law years ago would have saved millions squandered in litigation ; the "honest miner" having been very much inclined, if he had lost his vein, to endeavor to get hold of another, under the pretence that it was one of the "spurs, dips, or angles" of his own, — to use the jargon in which the notices of mining claims have always been written, excepting in the very few districts where "square claims" have been adopted by the miners. Provision is also made for enabling any miner to purchase and procure a patent for his claim, on paying for its survey, and at the rate of five dollars an acre for the land. In case of adverse claimants to the same piece of ground, the question of right has to be settled "by a court of competent jurisdiction." The miner, however, need not purchase, unless he sees fit to do so. The United States will not in any case molest him in his occupancy of the ground. This is not the place to go into any discussion of the crudities of the law in question, which bears all the marks of having been drawn up by lawyers with an eye to their own business, rather than to the good of the miner or of the country in general : certainly no competent mining-engineers could have been consulted in its preparation. By a subsequent Act, passed in 1873, "vacant coal-lands" are allowed to be entered at the price of ten dollars per acre, "if more than fifteen miles from a railroad, and twenty dollars if within that distance." The amount which may be so entered is limited to 160 acres for each person applying, or 320 in case of an "association of persons." Those actually in possession of coal-mines which they have opened and worked have the preference in making the entry, and may purchase an amount of land not exceeding 640 acres, provided as much as \$5,000 has been expended on the development of the property.

In regard to the collection of mining statistics, something has been attempted to be done by the government, but with

little success, since there are no laws requiring owners of mines to keep any record of their operations, or to furnish such, if kept, to a government official. The census mining returns, gathered every ten years, have sometimes been amusing from their absurdities, never of any value as statistics, except perhaps in the case of the census of 1870, with reference to the production of coal and iron.* To illustrate the utter worthlessness of our government mining statistics still further, it may be added that the "commissioner of mining statistics" reported, as the gold and silver product of the year 1870, the sum of \$61,500,000; the census returns of the same year give as the value of the "gold and silver mining product," \$26,452,652. Everybody posted in mining statistics knows that they are of little or no value, unless the sources from which they are obtained are under constant and efficient control by men of honesty and intelligence. In this country estimates of the amounts of the metals produced are simply guesses, which are valuable in proportion as the guesser has skill in weighing against each other and combining a great many facts bearing indirectly on the problem to be solved.

The establishment of a national mining school, under the control of some one of the departments at Washington, has been repeatedly advocated, and bills have been introduced in Congress with that end in view. As our government does not attempt in any way to interfere with or control the mining interest, it is difficult to see why a mining school should be supported by the nation, any more than a school of law or dentistry. The graduates of such a school would stand no more chance of employment than would those of any other institution. It is extremely desirable that our mines should be worked with skill and economy; but the establishment of a national mining school would not have the slightest effect in

* The superintendent of the census of 1860 estimated the amount of iron produced in the United States at 98 pounds for each man, woman, and child. To arrive at this result he added the total production of manufactured iron to that of the crude pig from which the manufactured was almost exclusively produced, — a proceeding exactly similar to what it would be if, to ascertain the weight per head of bread consumed in any town, one were to add the weight of the flour sold to that of the bread produced in order to arrive at the total to be divided by the number of persons.

bringing about the wished-for result. It is very desirable that Congress should pass laws regulating the sale of the mineral lands in a manner consistent with the well-established principles of political economy, and that a sound knowledge of geology and mining should form the basis of those laws. But if the most accomplished and the most honest mining engineers in the country were to offer their gratuitous services to the authorities at Washington for the purpose of helping to draw up the necessary laws, they would simply be laughed at for their pains.

It must not be supposed, however, that because the general government has wretchedly mismanaged the mineral lands belonging to the public domain, that our mining resources have not been rapidly and extensively developed. Our produce of iron is enormous, second only to that of Great Britain: the increase in the amount of coal mined is rapid, and indicates the steady expansion of our manufacturing interests. The gold of California has been washed from the surface detritus with feverish haste; and now the silver-mines of Nevada are the scene of the most extensive mining operations the world has ever seen. Nature has been prodigal in her gifts to our people; and we have been and are, perhaps, not more wasteful of our mineral than of our agricultural resources. The future will show how haste has made waste; but there is not the slightest reason to expect any change at present. As the development of the great permanent mineral interests, those of coal and iron, is chiefly in the older States, where the general government has no claim to interfere, having no ownership in the land, we may expect to see the individual States, at no very distant period, making necessary and desirable regulations for the health and safety of the miners and the people living in the neighborhood of underground workings; and economy, the result of skilful management, will come into fashion when the country has been forced into it,—a process which, as some think, has already commenced. A thorough knowledge of the geological structure of the country will form a sound basis on which the economical development of its mineral resources may rest; and of what has been done in this direction by United States and State authority we may now proceed to furnish a sketch.

The first step in geological science in this country dates back as far as 1807, when William Maclure, quite unaided and alone, commenced the exploration of the structure of the Appalachian chain, and the region lying between that range and the Atlantic coast. This was before William Smith's Geological Map of England had been issued ; but this pioneer in the science had already, seventeen years before, given to the world his "Tabular View of the British Strata," in which, for the first time, any part of the series of fossiliferous rocks, which make up so large a portion of the visible crust of the earth, had been arranged in the order of their formation. The Geological Society of London had just been founded, and the science of geology had suddenly begun to exist, and to command attention among educated men throughout Europe. Unfortunately the rocks of which the order of superposition was first worked out in England were quite different in geological age from those which largely predominate on the Atlantic slope and in the Valley of the Mississippi. Had this been otherwise, had the Silurian and Devonian formations, which cover so large a part of our own territory, been equally important and well defined in England, the task set before the earlier explorers here would have been much simplified. As it was, they had to wait for thirty years before Sedgwick and Murchison solved the difficulties presented by the Palæozoic system in Wales and on its borders, and gave our geologists the material for comparing their results with those which had been obtained elsewhere. It was no wonder then that Maclure found himself involved in a maze of difficulties : the work he had undertaken was far too comprehensive for any one man to accomplish. His geological map, however, did roughly indicate the character of the formations over an extensive area ; and, considering the circumstances, it may be said with truth that this first step was one which should be remembered as a worthy beginning of American geology. An "American Geological Society" was formed in 1818, under the leadership of Maclure, although its existence was but short-lived ; and the same was the case with the "Pennsylvania Geological Society," which was originated in 1832. The "Mineralogical Journal" of Dr. Bruce, also of

brief duration, and the "American Journal of Science," established by Professor Silliman in 1818, which has held out up to the present time, were indications of incipient activity in the direction of mineralogical and geological research. Amos Eaton was the first person in this country to make what we should now call a "geological survey," that is, a detailed examination of some special district, with a view to the elucidation of its geological structure and mineral resources. This survey was of the route of the Erie Canal; it was paid for by Stephen Van Rensselaer, and the results published in 1824. Here again the same difficulty presented itself which met Maclure; the rocks and fossils were unlike those best known in England, and the puzzle was so complicated that one man, in a short space of time, could do almost nothing towards its unravelling. There was but little accomplished except to call attention to some of the most prominent varieties of rocks, without any attempt to find out much about the fossils they contained, the science of palæontology being then indeed in its infancy. At the time when Eaton's work was done, the mining and smelting of iron ores had already become of very considerable importance, our yield of pig-metal reaching, in the year 1830, 165,000 tons; anthracite coal was beginning to come into general use, the Lehigh region supplying the market exclusively from 1820 to 1825, while the Schuylkill and Lackawana districts were opened between 1825 and 1830, when the quantity mined had risen to nearly half a million tons per annum. The smelting of lead was also just becoming a business of importance in the Mississippi Valley; but there was little else worthy of notice doing in the way of the development of our metalliferous resources. The discovery of gold in the surface detritus had, however, created a great excitement throughout the Atlantic States from Virginia south; and no doubt this was one of the principal causes of the sudden rise into prominence of geological and mineralogical studies in this country, and of the starting of a large number of State surveys just about this time.

A recognition of the science of geology by the general government seems to have been first made by the appointment of Mr. Featherstonhaugh, an Englishman, "to examine geologi-

cally the Territory of Arkansas and the adjacent public lands," which, at that time, in 1834, namely, might be taken to mean almost any part of the Mississippi Valley. This gentleman, who took the title of "United States Geologist," examined the country and published a geological section extending from the Atlantic Ocean, through Illinois and Missouri, to Texas; but his printed report contains hardly anything of value. All the limestones of the West were grouped by him in one formation, which he considered to be identical with the English carboniferous. His work was but little, if at all, in advance of that of Eaton, done ten years earlier, while the science had in that time made great advances, especially in England.

In 1839, Congress passed a resolution requesting the President to prepare "a plan for the sale of the public mineral lands," and also to cause surveys to be made for the purpose of getting information "relative to their location, value, productiveness, and occupancy." From the documents published the next year, it would appear that no other mineral lands were intended to be embraced in this inquiry than those of the Upper Mississippi Valley. The idea of mining any farther west than this was hardly dreamed of at that time. At least, it seems to have been expected that the work of exploration would be completed within three or four months, and Dr. D. D. Owen was appointed "principal agent" for that purpose. His report, made early in 1840, was limited to the lead region of Wisconsin, and contained the first approximate indication of the outlines of the geology of that State to the south of the river of the same name, and also of Northeastern Iowa. At this time considerable progress had been made in working out the geology of New York and Pennsylvania, and it was not difficult to take a long step in advance of Mr. Featherstonhaugh; so that the rocks of the region in question were correctly referred to the Silurian system, and the natural groups into which they were divided were indicated with considerable accuracy.

A few years later, namely in 1847, the subject of the disposition of the public mineral lands was again before Congress, and this time with reference to the copper region of Lake Superior, about which there was great excitement throughout the country from 1844 on for several years. On this occasion

two new geological surveys were ordered, one of the Upper Peninsula of Michigan,—the Lake Superior Land District,—the other of the Chippeway Land District, embracing an extensive area in Wisconsin, Minnesota, and Iowa. The results of both these surveys, accompanied by maps on which the tracts designated as mineral lands were indicated, were published in 1850–52, and were much more elaborate in their character than anything which had been previously done in this way by the general government. The geological formations were marked out and classified, over that extensive area, essentially in the way in which they now are, later surveys having made but few additions except of details. The great extent and value of the iron region of Lake Superior were then, for the first time, made known. These surveys did not, however, as has been shown already, lead to any general plan for the disposition or the care of the mineral lands. It was not until nearly twenty years later that this was attempted.

After the discovery of the gold of California, which happened just about the time that the Lake Superior speculations, or the “copper fever,” as it was generally called, had subsided into comparative quietude, the attention of the government began to be more and more called in the direction of a West, a long distance farther off than what had been previously known as the “Far West.” When the importance of the mining interests of California had been demonstrated,—and this needed but a brief space of time, the yield of gold rising almost immediately to figures entirely unparalleled in the world’s history,—it might naturally have been expected that Congress would set on foot a careful reconnoissance of the region west of the Rocky Mountains, a region of a million of square miles nearly, absolutely unknown, so far as its geology and mineral resources were concerned, but which, judging from what had long been known of Mexico, of whose Cordilleras ours were evidently the continuation, might be expected to be pre-eminently the mining region of the country. Nothing of the kind was done. Our legislators seemed entirely unable to grapple with any of the problems presented in that exceptional region. Each of the Pacific Railroad surveying parties, as already mentioned, was accompanied by one or more persons whose duty it was to collect in all

departments of natural history, and to study the geological structure of the regions traversed. Owing to the inexperience of most of the observers, and the rapidity with which the vast area was explored, almost nothing was accomplished in the way of throwing light on the mineral resources of the country west of the Rocky Mountains. Hardly one of the important problems presented in the field of general geology was solved. What was done was almost exclusively along the Pacific coast, the Rocky Mountain ranges and the great interior basin between them and the Sierra Nevada having been quite neglected. Hence it was, that up to the time of the commencement of the California State survey, no evidence had been obtained with regard to the age of the auriferous rocks of the California gold region; neither had it been discovered that the rocks about San Francisco were of Cretaceous age; and the very existence of this member of the series was quite unsuspected, although it forms the main body of the Coast Ranges, from Monterey north, and also occurs in large isolated areas on the flanks of the Sierra. Moreover, there was nothing known of the geological position of the high gravels worked for gold by the hydraulic process; nor had anything been discovered in regard to the occurrence of the Alpine Trias over a vast area in Western Nevada, a group of rocks extending from Mexico to Alaska, and replete with that peculiar assemblage of organic forms which has attracted so much attention in Europe. Indeed, nothing had been made out about either the geological age or the structure of any part of the Great Basin beyond what the collections made by Fremont had revealed. And in the Rocky Mountains proper, — the eastern edge of the Cordilleras, — all was entirely a *terra incognita* so far as its structure and the nature of its fossiliferous groups were concerned.

Our knowledge of the geology of the "Great Northwest," as the vast region of the Upper Missouri at the base of the Rocky Mountains may be called, has been developed gradually, beginning with the days of Lewis and Clarke. These pioneer explorers brought back with them fossils enough to enable Morton to determine the existence of the Cretaceous series in that region, and twenty-five years later Prince Maximilian of Neuwied obtained additional evidence of the same fact; and

again, in 1839, Mr. Nicollet acquired some information with regard to the extent of the area over which these rocks were extended. The first knowledge of the wonderful Tertiary fauna of the region of the so-called "Bad Lands" — the Mauvaises Terres of White River — was obtained by means of a bone sent in 1847 from one of the posts of the St. Louis Fur Trading Company to Dr. H. C. Prout of that city. The region was explored, ten years later, by one of Dr. D. D. Owen's assistants, who was then engaged in the survey of the Chippeway Land District, as before noticed. The fossils thus obtained, and those afterwards brought from that region by Mr. Culbertson, and other collectors, were described by Dr. Leidy, and proved to be of the greatest interest.

In 1853 two gentlemen visited the Mauvaises Terres, whose names are identified with the progress of geology in the Northwest, namely, the indefatigable explorer, Dr. F. V. Hayden, and the eminent palæontologist, Mr. F. B. Meek. This expedition, which was made at the expense of Professor James Hall, laid the foundation of our knowledge of the geological structure of that region; and almost the whole of what we now know of the geology of the Rocky Mountains is based on the work carried on or superintended by Dr. Hayden, almost uninterruptedly since 1853, and during most of the time under the authority of the Department of War or of the Interior at Washington. Those who are acquainted with the progress of American geology will not need to have it stated that the value of Dr. Hayden's work has been greatly increased by the thoroughly trustworthy and conscientious manner in which his extensive collections of fossils have been worked up, not only, and chiefly, by Mr. Meek, but also by Messrs. Leidy and Lesquereux. Dr. Hayden accompanied the expeditions of General Warren and General Reynolds, to which allusion has already been made, and in which the region of the Upper Missouri and the Yellowstone was reconnoitred. These explorations were followed by the appropriation by Congress of a small unexpended balance, made originally for defraying the expenses of legislation in Nebraska, for the purposes of a geological survey of that Territory. Under that authority Dr. Hayden was appointed United States Geologist in 1867; and the appropriation was

renewed the next year, with directions that the survey should be extended into Wyoming, and, if time permitted, as far as the South Park in Colorado. The work thus begun became first the "United States Geological Survey of the Territories," and later, as already mentioned, the "Geographical and Geological Survey of the Territories." Under this organization, the geological corps being reinforced by a topographical one, the work has gained greatly in scope and value, the appropriation having been liberally increased in amount; so that, if the organization could be made a permanent one, and not be, as it is, absolutely dependent on the whim of each successive Congress, we should have reason to look forward to a most satisfactory working up of the topography and general geology of the Cordilleras. Some geological work has been done in connection with Major Powell's survey of the Colorado, and the Wheeler Survey, under the United States Engineer Bureau, to which allusion has already been made; but nothing of importance has yet been published by either corps, so that no judgment can be formed in regard to the method or value of the work. The remarks made in reference to the manner in which the Departments of War and the Interior are duplicating each other's topographical work applies equally to the geological. The last volume of Hayden's Survey — the Annual Report of the explorations of the year 1873 — shows a gratifying advance over the preceding ones, in respect to the real value and accuracy of the geological material it contains.

The geological results of the "Fortieth Parallel Survey," in charge of Mr. Clarence King, are not yet published; but it is understood that one or more volumes are well advanced towards completion, and that they will soon be issued. We confidently expect to find in them a very large amount of new material of great importance, as throwing light on the structure of an extensive area, which Mr. King, with the large means put at his disposal by Congress, and the aid of an excellent corps of assistants, has had a fine opportunity to work out in considerable detail. The volume of "Mining Industry," published three years ago, and chiefly devoted to the detailed description of the most important mineral vein in the world, — the Comstock lode, — is a superb piece of work, and far in

advance of anything previously done in this country in the same line, and we know of nothing published in Europe superior to it. And it should not be forgotten that the high character of the work done by the Fortieth Parallel Survey was the cause of a great advance in the methods and aims of the other surveys which have their headquarters at Washington. This was especially the case with regard to Dr. Hayden's work, with which Mr. King's chief topographer, Mr. Gardner, and some of his assistants, became connected, thus rendering it probable that some degree of uniformity would be maintained in the extension of the topographical surveys which from that time forward became an essential part of what was previously only the "United States Geological Survey of the Territories"; that is, a geological survey without any geographical basis.

Of the various geological surveys instituted during the past fifty years by the individual States, it will not be possible to speak in detail. But this can be said, in regard to them all, that they are only reconnoissances. There is not one which rises to the standard of the European surveys, or which is based on an accurate geographical map. Neither has any such survey been made as can be looked on as a finality, or which is so considered by the people. For instance, not one of the coal-bearing States has carried its survey to such an extent of accuracy as is necessary in order that the quantity of this all-important material existing within its borders may be known even approximately. In no State has the economical value of its metalliferous ores been satisfactorily worked out. Neither is there one in which the character and distribution of the soils and superficial detritus have been made a subject of careful study, as has been done in Holland and is now doing in Prussia. The reasons for this condition of things may be discussed after a brief sketch of the development of these surveys in the different States has been given.

As it is generally stated that North Carolina was the first of the States to conceive the idea of having its mineral resources investigated at the public expense, it may be well to state that the idea originated (in 1821) with a Connecticut schoolmaster, Denison Olmsted, who was then acting as Professor of Chemistry in the University at Chapel Hill; and it

may also be mentioned that the — not overpowering — sum demanded for the work, namely one hundred dollars, was never received from the State treasury ; so that the credit, if there be any, must be fairly set down as belonging to Connecticut rather than to North Carolina. The report itself was as creditable a one as could have been expected under the circumstances. Considerable information was collected in regard to the occurrence and value of the ores, minerals, and rocks of the State. The Deep River coal-field and the sandstones accompanying it were described, and referred pretty nearly to their true place in the geological series.

Something similar was attempted about the same time in South Carolina, but the results were never published, except in the form of communications to the newspapers. The geologist employed, Lardner Vanuxem, a native of Philadelphia, was — so far as is known to the writer — the first American educated abroad to the profession of mining engineer ; and his scientific training stood him in good stead, a few years later, when he took charge of one of the districts into which the State of New York was divided, for the purposes of a geological survey. At this time the number of persons in the United States who had received what we should now call a scientific education must have been exceedingly small. There was no institution in the country where anything more than the rudiments of chemistry, mineralogy, and geology was taught ; and it appears that there were only two or three persons, among all the earlier State geologists, who had had the opportunity of pursuing these studies in Europe, so that the first business of most of them, on entering upon their respective fields of labor, must have been to teach themselves.

Massachusetts was, in point of fact, the first State to inaugurate a geological survey, the beginning of the topographical work already mentioned having been very soon followed by the appointment, as State Geologist, of Rev. Edward Hitchcock, a gentleman who had become known through various papers in the “ American Journal of Science ” relating to the geology of the Connecticut River Valley. This appointment was made in 1830, and the work went on, with some stoppages, for about ten years. What was at first intended as a final report was

published in 1833 ; but a re-examination of the State was then ordered, and the completed work was issued, in two quarto volumes, in 1841. This was followed by a long series of publications, issued by the various States, the volumes having succeeded each other rapidly, until now quite a library of them has accumulated. Between 1833 and 1836 nearly every one of the Eastern and Middle, and several of the Western, States commenced their geological surveys, — first Tennessee, then Maryland, followed by New Jersey, Virginia, Pennsylvania, Ohio, Michigan, Indiana, Kentucky, and several of the smaller States. In few of these cases did the work go on to what was, even then, considered a satisfactory completion ; in most instances it was stopped after one or more annual reports had been made. New Jersey was for a time satisfied with Professor H. D. Rogers's final report, published in 1840 ; but the work has, since then, been several times taken up, and now the geological survey seems to have become a fixed institution in the State. The present State Geologist, Professor G. H. Cook, has annually, every year since 1868, made a brief report on some special subject of economical importance to the people. The earlier surveys of Ohio, Kentucky, Indiana, Michigan, Virginia, and Tennessee, in fact of all the large States except New York and Pennsylvania, were abandoned, and before anything like a complete reconnoissance had been made. In all these States, however, with the exception of Virginia, the abandoned surveys have been taken up again, and in some cases there have been several renewals and stoppages of the work.

Of all the earlier State surveys, those of New York and Pennsylvania were the only ones which became of considerable importance, and really contributed in a marked degree to influence the development of geological science in this country. These surveys were both begun in 1836, that of Pennsylvania being strictly limited to geology ; while in New York several branches of natural history, as well as agriculture, were to be made the subjects of special reports. New York is a State of large area, rich agriculturally, and having great manufacturing resources. For her coal, however, she has to depend on her neighbors in the South and West, as she has, herself, no

workable deposits of that invaluable material. Mining is of very secondary importance in New York, as the only metalliferous ores which have been hitherto worked with profit are those of iron. The manufacture of salt from the brines obtained by boring in the central part of the State has, however, long been an important branch of industry. Hence the economical aspects of the geological survey were of secondary importance, and the particular interest attaching to the work was due to the fact that here the sequence of the geological formations, from the base of the Carboniferous down to the very bottom of the fossiliferous rocks, including the Devonian and the Upper and Lower Silurian, was first completely worked out in this country, and the fossils characteristic of each group and subgroup figured and described. And since these Palæozoic rocks of New York extend far and wide over the Valley of the Mississippi, — as far as Lake Superior on the north, and to Iowa and Missouri in the south and west, — the volumes of the “Palæontology of New York,” by Professor James Hall, which have been issued from time to time since 1847, have been the indispensable guide to our Western geologists, as they have gradually extended the area of their investigations over the interior of the continent. The sequence of the different groups was easily made out in New York, because there they lie conformably on each other, without having been much moved from their original position. In New England, on the other hand, rocks of the same geological age as those of New York cover a large portion of the surface ; but, instead of remaining nearly as they were deposited, they are broken, turned up on edge, and folded, the fossils they once contained having been almost entirely obliterated, and their very inmost structure changed by chemical agencies acting under the influence of heat and pressure. Thus, while all was plain and easy to decipher on the west of the Hudson, on the other side all was doubt and difficulty, so far, at least, as the geological age and position of the strata were concerned. Under these circumstances it has only been by slow degrees, and chiefly by comparison of results attained on our northern borders by the Canada survey, and also, from time to time, by discoveries of little patches of rocks in which the fossils have not become entirely obliterated, that

the outlines of New England geology have been made out; and this has been almost entirely accomplished since the publication of Dr. Hitchcock's Final Report.

Although the Pennsylvania survey was begun in 1836, nothing was published, excepting a few meagre annual reports issued in the first years of the work, until the year 1858, when the Final Report, in three quarto volumes, was given to the world. The engraving and printing of these were done in Scotland, and in a style of great perfection and elegance. But the publication of the results of this survey had been so long delayed that a portion of its value was lost. The nomenclature proposed for the different groups of the palæozoic series never was adopted, that of the New York survey having already become familiar to American geologists; and as no attempt was made to work up the palæontology, except so far as the plants of the carboniferous series were concerned, these beautiful volumes can only be said to have had a local importance, being especially valuable for their details of the coal-bearing rocks, in regard to which a great amount of detailed information was laid before the public. More than any State in the Union, Pennsylvania needs an exhaustive geological survey, based on a thoroughly accurate geographical one. Her coal and iron deposits are on such a scale of magnitude, and of such vast commercial importance, that it is safe to say that the time will surely come when this will be recognized, and the people will demand a style of work equal to that of the best European surveys. Quite recently, after nearly twenty years of repose, the work of a geological examination of this State has, indeed, been taken up again. It does not appear, however, that this new work is to be based on and preceded by an accurate trigonometrical survey. Unless we are misinformed, it is, on the contrary, to be limited to three years in duration; and already a final report on one important object of investigation, petroleum, is spoken of as being ready for delivery, although it has not come into the hands of the writer. It is safe to say, therefore, that Pennsylvania will yet demand a higher class of work, and it may be that this will become evident to the people, while the present survey is in progress, so that this may be allowed to develop itself until it reaches

the desired degree of completeness; if not, the work will surely be resumed at some future time; while the loss thus incurred, by putting off until some distant day the thorough investigation of the resources of the State, although not appreciated by the present generation, will become very evident when the people have become educated up to a proper understanding of these matters. The attempt to supply an accurate map of a small area of the anthracite region, made by private parties, is well as far as it goes; but private surveys can never carry that weight which public ones do, neither can they by any possibility reach the requisite degree of precision, unless limited to a very narrow area.

Virginia, which is also a State presenting a most attractive field to the geologist, — and in making this statement we may include both Virginia proper and West Virginia, — has done nothing in the way of a survey during the last thirty-five years. The detailed study of its topographic and geological structure would be a work of great interest, and could hardly fail to be at once remunerative to the State. Ohio, Indiana, Illinois, and Kentucky, four States which have large areas of coal-bearing land within their borders, and which also possess great agricultural resources, all have surveys in progress, which are more or less continuations of work begun forty years ago and taken up and dropped, in some instances, several times, and under different heads. In Ohio and Illinois the publication of what appear to be intended as Final Reports is drawing to a close, — the field-work, as it seems, having been finished. In Illinois five large volumes have been issued, which form a worthy supplement to the Palæontology of New York, being chiefly interesting from their contents in this department. Valuable material of the same kind is found in the two published volumes of the Ohio Survey, and a large amount of detail in regard to the coal and iron resources of the State. To thoroughly work out the questions of economical interest which are offered by the great States of the Mississippi Valley will be a very serious undertaking. The surface throughout this part of the country is everywhere only moderately undulating; but the streams — which are very numerous — have cut themselves valleys which vary considerably in depth and

width, in different sections. This erosion of the river-valleys, taken together with the general irregular wearing away of the surface by atmospheric causes, and the action, over a portion of the region, of the northern drift currents, have given rise to a kind of topography which requires a very minutely detailed study if the geology is to be laid down with accuracy. And, as the coal measures often lie quite near the surface, it will be easily understood that the amount of denudation which has taken place becomes a very important element in arriving at a knowledge of their extent and value. The time will come when this detailed work will have to be done ; but it is perhaps not to be expected that so extensive and costly an undertaking should be entered upon at once.

From what has been said in the preceding pages, the reader will, it is hoped, have gathered some idea of the nature and scope of a geological survey. He will not fail to have noticed that, as in geographical, so in geological work, the reconnoissance is a very different thing from the thorough survey. And as it is only countries far advanced in wealth and civilization which can have accurate maps of their domains, so it is only those possessing accurate maps which can have their geological work thoroughly done. And the more detailed the investigations which are made in any region, the more practically valuable they are ; indeed, it may be said with truth, that it is only work which is detailed and thoroughly accurate that can be trusted and used, where a problem of economical importance, involving a considerable expenditure of money, is to be solved. The reconnoissance answers the purpose of satisfying the curiosity of the general public, and awakens scientific interest, by opening new problems for investigation ; but the capitalist and the miner can only use as a guide that which goes into minute details, giving measures and distances with accuracy.

Another circumstance must be taken into consideration ; that is, the necessity of a partial development, at least, of the mineral resources of a country, before much that is trustworthy can be ascertained about their value. It is much easier for the geologist, as for every one else, to see through the millstone after the hole has been bored in it. Indeed, in many in-

stances, the character of the surface of a country is absolutely no guide to what is beneath. What could any one have known of the marvellously intricate structure and wonderful development of the Belgian coal-fields before the rocks had been reached and laid open by shafts and borings carried down through the horizontal, undisturbed strata which overlie the crumpled and dislocated coal-measures beneath, from which that little busy country derives so much of its wealth? The geologist must have his opportunities; and especially the mining geologist, for each mining district has its peculiarities, and these can often hardly be guessed at before they have been revealed by actual working. It is only in the oldest and best-known mineral regions of Europe, where work has been carried on, uninterruptedly, for hundreds of years, that one can feel a tolerable degree of security in giving an opinion in regard to the value of a newly opened metalliferous deposit; and it is there that the importance and value of accurately kept records of previous work are shown to be of so much value. As a contrast to the completeness of our knowledge of what has been done and is doing in Europe, in the way of utilizing the mineral deposits of the various states, let the inquirer consider how little is definitely known of the present resources of Mexico and the South American countries, which have been so productive in the precious and other metals in former days. What a record of ignorance and waste is there displayed, and how wretched the net result to the people!

If our own geological surveys, begun when the science was almost in its infancy, and when, indeed, in this country everything was yet to be learned, have thus far had no considerable immediate practical value, they have been of great importance in the way of developing a taste for the natural sciences, which are all more or less included in the study of geology. And there was no other method by which progress could be made than that of beginning, and doing the best that could be done under the circumstances. The condition of things has greatly changed in this country since it was thought that the physician could leave his patients or the clergyman his pulpit, and give an authoritative opinion on the structure and mineral resources of the country. Schools of science are now numerous;

and some of them, at least, fairly well equipped for teaching those specialties which are needed for doing good work in geographical or geological surveys. Forty years ago there were, at the most, half a dozen Americans pursuing scientific studies in Europe; now the number may be counted, probably, by the hundred. Could the knowledge and ability we have in the land be economically and judiciously utilized, a large amount of first-class work could be done, and fine results obtained; and that, too, without any considerable increase in the expenditure beyond that which is now habitually incurred.

We come now to make a practical application of what has been said in the preceding pages, and in a previous article on geographical surveys, to the State of Massachusetts. Of what has been already done here mention has been made; and it has been noticed that the matter of a new survey was before the Legislature at its last session, and was the subject of a report from the "State Board of Education," to which the question had been confided for examination at the preceding session. The bill introduced for the purpose of organizing a topographical, geological, and biological survey of the Commonwealth failed to become a law, so that the subject remains open for discussion.

And before commencing an examination of some of the principal points to which attention ought to be given in this connection, it may be well to mention that the area of the State of Massachusetts is usually given at 7,800 square miles, while the population, by the census of 1870, was very nearly a million and a half of souls, so that we have an average density of 186 to the square mile. In the United Kingdom of Great Britain and Ireland there is an average of 260, in Belgium of 462, to the square mile. In Massachusetts the population is considerably more dense in the eastern than in the western and northwestern portions. The most thinly inhabited part of the State has also the most uneven surface, although there is but a comparatively small area which is too mountainous to be brought under cultivation. Massachusetts is essentially a manufacturing State: according to the last census the value of her manufactured products, in 1870, was nearly \$554,000,000, while the figures given for New York — with six times the

area and three times the population of Massachusetts — are \$785,000,000. The wealth of Massachusetts is only exceeded by that of New York and Pennsylvania, and is nearly double that of New York in proportion to its area. The metalliferous mines of this State are of little importance, but the quarries of building material are extensive; although, as compared with the manufacturing interest, the value of their product seems but trifling. The value of the iron mined was, in 1870, according to the Census Report, \$30,000; no other metalliferous ore is mentioned as having been worked in that year in Massachusetts; neither is there a record of any produce of coal. The value of the products of our quarries is given at \$1,362,648, or about $\frac{1}{400}$ of that of our manufactures. These are some of the principal data to be kept in mind, while discussing the subject of geographical and geological surveys with reference to the State in question.

It will be admitted by all that if any one of the United States can afford to carry on a thorough survey, it is Massachusetts. The density of her population is considerable, even as compared with that of some of the most thickly inhabited European states; her wealth is great, and the development of her commercial and manufacturing interests has been, and is, rapid. Land is valuable, and is likely to become more so from year to year, and economy and skill are needed in order that a State which has become wealthy rather by means of hard work and indomitable energy, than because she has been bountifully provided with natural resources, may continue to occupy a high relative position, in competition with other portions of the country which have a richer soil and a much greater supply of mineral or metallic wealth.

In considering what kind of a topographical survey is needed, we have to inquire how such a work is utilized after it has been completed, or, in other words, what is the pecuniary inducement for its prosecution. All would admit that it would be unwise to enter upon an undertaking which must of necessity be very expensive, without a clear understanding, at the outset, of the reasons why the expenditure is to be made. Besides, the scale and degree of accuracy of the work to be done depend on the use which is to be made of the results; until this

point has been settled, it would be idle to estimate its cost, or to attempt to limit the time of its completion. Now, the principal objects of the great topographical surveys in Europe are: *first*, to furnish the government with the necessary data for fairly and accurately determining and apportioning taxation; and, *second*, to make it possible for transfers of real estate to be made with ease and precision. In other words, the cadastral, topographical, or ordnance survey — by whatever name it may be called — is a part of the machinery of the government, and, as it appears to most civilized states, a necessary part. It is true, also, that topographical maps are of importance on the Continent, — where wars have been, and are likely to be, frequent, — for guiding the movements of armies; but this has been a consideration of little weight in England, and is still less to be taken into account here. The peaceful aspects of the subject need only occupy our attention. In addition to the great and all-important uses to which an accurate topographical map can be put, namely, those connected with taxation and the transfer of real estate, there are many other minor ones, which have already, in part, been suggested in the preceding article on this subject. It can be said with truth, however, that we have had no such accurate surveys as are going on in the different European states, because here the people do not know the uses to which such work is put, while there the government does know. It is, therefore, most reasonable to suppose that, in a country where the people are the government, the necessary preliminary to such a work as that we are now discussing will be increased knowledge on the part of the people. Let them but once fully comprehend the advantages which such a survey offers, when well done, and they would never be willing to do without it. Let the work be begun without a full understanding, and a settlement by legislation, of the uses to which it is to be put, and the probability is strong that it would be stopped, as soon as a “realizing sense” of its cost began to be felt. Hence we argue that, instead of beginning another Hoosac Tunnel, which is sure to cost a great deal, and which perhaps there may not be intelligence enough in the State to utilize after it is done, the subject of a thorough survey be fully investigated by a competent commission of ex-

perts, who themselves have no axes to grind, and who are not looking chiefly to the question of how their own pockets are to be affected by the transaction. Let such a commission, we say, find out by careful inquiry how work of this kind is done in Europe, and how utilized there; and then let them investigate the question whether the conditions in this country are such that it is possible for us to reap the full advantage of so costly an undertaking. A careful discussion of the subject should precede final action.

The crudeness of the Report of the Board of Education is indeed remarkable; and, in looking it over carefully, it is difficult to avoid the conclusion that the members of the Board, knowing nothing practically of these matters, have allowed themselves to be counselled by those who, from motives which it is not difficult to divine, were more anxious to have the work done, than to have it well done. It seems a pity that, after forty years of supposed development and improvement, the Legislature and the people of Massachusetts should find themselves, in reference to the question of a topographical survey, about where they were in 1830, ignorant of the nature and use of the work proposed, misinformed in regard to the methods required for doing it accurately, and led all astray in the important matter of its cost. Indeed, the main object of the report seems to have been to create the impression that the whole thing can be accomplished with but a trifling expenditure; that is, for less than a tenth part of what it is thought necessary to expend, per square mile of area surveyed, on the Ordnance Survey of Great Britain and Ireland. To make this appear reasonable, it is suggested that the old Borden triangulation can be utilized; and then, it is added, that Congress having provided that the Coast Survey shall "determine the necessary triangulating points in every State which shall make appropriations for a topographical survey," therefore the triangulation can be done at the expense of the United States. Thus it appears that two different triangulations are to be used in the new survey, neither of which is to cost the State of Massachusetts a penny; but how the two are to be combined so as to form one harmonious whole is a problem on which no light is thrown in the Report. The idea is simply an absurdity.

Any one acquainted with these matters would recognize the fact at once that the old Borden triangulation could not be used in a new survey, under any circumstances; that, even supposing it were accurate enough, it would be more expensive to determine the position of the old stations than it would be to make new ones; and if Mr. Borden's work is to be made use of, all his stations will have to be occupied again for the secondary and tertiary triangulations, which never were made in the previous survey. The idea, also, that the United States can be relied on to furnish the main triangulation seems to us a delusion. As has already been shown, if the whole amount appropriated by Congress for this kind of work were to be expended in Massachusetts, it would only enable the Coast Survey to carry on the triangulation with a moderate degree of rapidity, and it would certainly require several years for its completion. And does any one suppose that it will be possible to limit to one State only the expenditure of money which is now carefully spread over a dozen or more States, in accordance with the usual method of not favoring one part of the country more than another, when the United States treasury is to pay the bills? Or is it fair to take it for granted that it will be possible to secure from Congress so large an increase of the appropriation for this special purpose as would be necessary in order that a triangulation should be made of the whole country? And, if granted for one year, what security would there be of its continuance during the next? Besides, there are other reasons why the whole survey, including the primary triangulation, should be done by the State itself; but to enter into a full discussion of the subject would require too much space and too many technicalities, and this must be left for a more suitable occasion. A thorough investigation of the whole matter would settle this, as well as the other points which have been suggested. The recommendation that, for the contour lines, "exact measurements be taken only every one hundred feet, and that the auxiliary lines between them be filled in by the topographer on the spot," might mean something in a mountainous country, where minute accuracy was not deemed essential; but such a style of work is entirely unsuited to the nature of the surface of this State, and the character of the

results which will have to be obtained, if the survey is to be one of permanent value, and to be utilized for the purposes set forth in the Report in question.* It is therefore not right or reasonable that the impression should be given that a topographical survey of Massachusetts can be made for \$175,000, which is the estimate of its cost made by the Board of Education. The old triangulation, only partially completed, cost nearly half that sum, and it was executed at a time when one dollar meant at least three times as much as it does now.

In regard to the geological part of the contemplated survey, the first thing to be considered is this; that the geology cannot be put upon the map, before the map is ready to receive it. The geological and geographical work cannot be carried on *pari passu*, without loss of time, increase of expense, and liability to error. The painter would not be asked to furnish a picture, unless he had a canvas on which to work. All familiar with geological field-work know that it is impossible to proceed with accuracy and rapidity, except map in hand. The organization of a geological survey then should be deferred, until some of the sheets of the geographical map are done and engraved; and this must, under any circumstances, occupy several years. But, of all the States of the Union, Massachusetts is one which has least need of a geological survey. This is not a region rich in mineral resources, and it never will be, no matter with how much care its geological structure is investigated. The impression is given in the Report of the Board of Education, that a survey will "develop our coal-fields," and transform us into an important mining community. This is a delusion: if our coal-fields are ever developed,—that is, if their extent and value become thoroughly known, and it be found that they can be worked with profit,—it will be after

* To illustrate this, it may be mentioned that in the Connecticut River Valley the points at which the "exact measurements" were taken would be about fifty miles apart! That is, if a hydraulic engineer at Springfield wished to get some accurate information from the State Survey for use at that place, he would find on examination that there was a point, the altitude of which had been fixed with precision on purpose for his convenience, and he would find it — at Greenfield, or possibly at Northampton! And similar conditions will obtain in all our river valleys, where the fall is but slight, and, consequently, differences of level of a few inches will be of the greatest importance.

many and expensive underground explorations have been made by boring and otherwise, and when, so far as we can now foresee, conditions shall have become quite different from what they now are. Previous attempts to make our coal-mines profitable have failed, not for want of means and experience in coal-mining generally, but because the rocks are too much broken up, and the coal-beds themselves too irregular in thickness and position, to make it possible to open and work them without loss.

It is no part of the work of a geological survey to "develop" either coal-fields or metalliferous veins. Development must come from actual working, or from systematic exploration by numerous and expensive borings. That this should be done at the cost of the State would, no doubt, be agreeable to the owners of the land beneath whose surface our coal-fields are presumed to lie; but it would hardly be considered by the people as a legitimate expenditure of their money.

There are within the borders of this State several large and well-defined veins in which argentiferous lead and copper ores occur in considerable quantity. At the time of Dr. Hitchcock's survey, they were considered by him as likely to be "of great value to posterity, if not to the present generation." All the attempts at working them have, however, proved to be unprofitable ventures; although a great deal of money has been spent in this way at various times since 1765. The same has been the case with the other metalliferous veins of New England; almost without exception the mines which have been opened on them have been disastrous failures. Eaton, Shelburne, and Warren, in New Hampshire, may be cited as typical localities, where flattering surface indications have led to extensive mining operations, without any permanently valuable results; and it is now many years since these workings were abandoned, with but little chance of being resumed. These facts should be borne in mind by those who are disposed to look on every new discovery of metalliferous ore within our borders as likely to lead to developments of great importance. The experience of the past teaches the necessity of great caution in the expenditure of money on mineral veins anywhere in New England, however flattering may be the surface indications.

That wild speculations and hap-hazard investments in entirely undeveloped mines are not likely to be followed by results favorable either to the individuals concerned or the community in general may also be pretty safely affirmed.

The structural geology of Massachusetts is not well understood, nor will it be for many years to come, for reasons which have already been hinted at in the preceding pages. Little by little it will be worked out; but a geologist appointed by the State will have few advantages over those which have been possessed by the ablest men in the profession who have, from time to time, tried their hand at deciphering the puzzle, having no other motive than the interest which it presents to the scientific inquirer. Professor Dana, our ablest structural geologist, has studied the hills of Berkshire, and begun the elucidation of their structure. James Hall, Henry D. Rogers, and others, have done the same. If the Legislature wishes to spend money in this way, let it be done; but it would be wrong to let it be thought that any report on the geology which might be the result of the expenditure would be a finality, so far as the geological structure of the State is concerned, or that it would be of much importance in the way of developing unknown mineral treasures beneath the surface.

It appears to the writer, however, that there is a way in which a State, situated as is Massachusetts in respect to geology and mining, may not only do good service to science, but also receive a *quid pro quo* in the way of valuable information on questions of economical importance to the people. All will admit that it is desirable that there should be somewhere in each State a trustworthy source of information in regard to the mode of occurrence and value of the various minerals and metalliferous ores which are, or are thought to be, from time to time discovered. And it is also desirable that a history of the development of the resources of the State, in this department of its industry, should be kept, and such statistics collected as it is possible, under our form of government, to procure. The question arises, how to have a permanent source of information on these subjects, which shall be out of the reach of politics and politicians, where one who does good work will feel secure in his position, and not be obliged to spend a con-

siderable portion of each year in lobbying his appropriation through the Legislature, a humiliating necessity, in connection with our State surveys, which is, of itself, enough to frighten off the best men from having any connection with these undertakings. We would say that the best method of bringing about these desirable results would be, for the State to endow a professorship of economical geology in some institution of learning, that one, of course, being selected which should be deemed likely to keep up the highest standard of honesty and ability among its professors. Coupled with this endowment should be a proviso, that the appointee should report to the executive either annually or biennially, on such subjects connected with the geology and mineral resources of the State as might seem to him to be of the most importance at the time. These reports could be laid before the Legislature, and printed or not, according to their value. If the person selected to fill the position were a man of high ability, no doubt his reports would command attention, and well repay the cost of printing, while their sale would defray a part or the whole of the expenditure. In this way a perennial source of information would be brought into existence, and the amount required for this purpose would not exceed that called for by the Board of Education for a geological survey, which would be limited in time, and, after all, only the expression of the opinions of one person, based on the information obtained during the short period of the continuance of his own work. For it must not be forgotten that much of that which is considered, in this country, as properly belonging to the business of a geological survey, is work which ought never to be brought to a close. New facts are always turning up, new discoveries are made, commercial and financial conditions change, new uses are found for old materials previously deemed of no value, accumulated experience and knowledge throw light on what was once obscure: all these circumstances indicate that the time will never arrive when everything will be known in regard to the geology of the State, and that it would be wise for the Legislature to recognize this, and make provision for gathering and systematizing the facts as they are developed, and for faithfully doing the best that can be done to make them available to the people.

J. D. WHITNEY.